Pollution Prevention in the Coastal Zone

NATIONAL POLLUTION PREVENTION CENTER FOR HIGHER EDUCATION

Sewage Sludge Pelletization in Boston: Moving Up the Pollution Prevention Hierarchy

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Introduction

Boston Harbor covers 130 square kilometers and has an average depth of 5.8 meters.[1] The only route through which Boston coastal waters are flushed to deeper waters is east through Massachusetts Bay. The Harbor once supported abundant, healthy populations of harbor seals, porpoises, whales, sea birds, and many types of marketable fish and shellfish. However, after centuries of raw sewage and sludge discharges to the Harbor, stocks of these species have suffered.[2] By the time the Boston Harbor Clean-up Project began in 1986, sewage scum had formed noticeable slicks in local waters, while discharged sludge added solids, toxins, and pathogens.[3] Years of litigation prompted the Project, which has implemented upgrades in sewage handling and discharge.

POLLUTION PREVENTION HIERARCHY
as established by Congress in the
Pollution Prevention Act of 1990

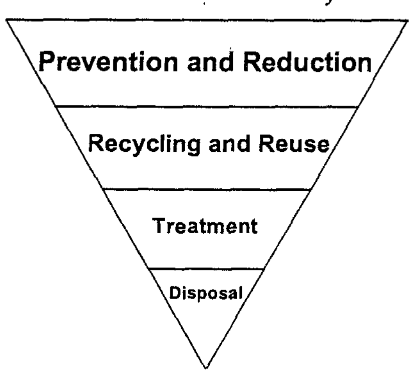

FIGURE 1:
THE POLLUTION PREVENTION HIERARCHY

Under court orders, there is a new wastewater treatment plant and improved sludge disposal techniques. In addition, officials are updating and improving the entire sewage system through collection pipe replacement, renovation of pump stations, and improved headworks. With the increased sewage treatment, some species of fauna are already reappearing in significant numbers, raising hopes for further improvements following the completion of sewer upgrades.

As Boston wastewater treatment strategies have climbed the pollution prevention hierarchy (see **Figure 1**), one important change has been external reuse of sewage sludge: The Quincy Pelletizing Plant transforms sludge into fertilizer.

Policy

The Clean Water Act of 1972 (CWA) required that publicly owned treatment works (POTWs) provide secondary treatment of sewage by mid-1977. Through its construction grants program, CWA would have provided up to 75% of the construction costs. However, after passage of the 1977 CWA Amendments, the Metropolitan District Commission (MDC) suspended planning for system upgrades.

Under amended CWA section 301(h), if POTWs could prove their discharges would not adversely affect water quality or marine ecosystems, they could ask the U.S. EPA to waive the secondary treatment requirement. The MDC applied for a waiver in 1979, arguing that the benefits of secondary treatment were not worth the costs[4] and that it preferred to upgrade the antiquated primary treatment plants at Deer and Nut Islands and construct ocean outfalls with multiple diffusers. The EPA denied MDC's first application in 1983 and another in 1985.[5] During this 13-year process, sewage treatment improved little and the condition of the Harbor declined.

Before the renovation of Boston's waterfront began in the early 1980s, the public had not rallied around the banner of a clean harbor and improved water quality: The main transport artery and large buildings separated downtown from the ocean, and those who did notice the deterioration of the water quality and beaches had no means to convey their frustration. Beach-goers were primarily lower- to middle-income Bostonians with little formal political clout, while fisherman simply did not want to announce to the public that their product was substandard. Legislators were interested in more visible projects, such as roads and parks.[6]

William Golden, City Solicitor for Quincy, was the first public official to openly acknowledge the deteriorated state of Boston Harbor. His outburst was prompted by his experience during a beach jog: he thought that he was running on raw sewage.[7] According to a former MWRA employee, it was actually algae. However, in 1982, Golden persuaded the City of Quincy to sue the MDC for violation of the Massachusetts Clean Water Act.[8] Quincy demanded a moratorium on both sewer tie-ins and expansion projects in the 43 communities using the MDC sewage system.[9]

On June 7, 1983, the Boston-based Conservation Law Foundation (CLF) joined the campaign and initiated a federal action against the MDC and the EPA.[10] The suit requested an injunction due to chronic, unauthorized, massive sewage discharge by the MDC in violation of the CWA. The CLF also argued that the EPA failed to perform its non-discretionary duties under the CWA to require the MDC to comply.

The federal case was stayed while, at the state level, Judge Paul Garrity succeeded in getting MDC to sign a procedural order to comply with a court-ordered schedule to clean up the harbor. However, during the next year, no clean-up activities occurred. Therefore, on November 29, 1984, Garrity imposed a ban on new connections to the MDC system. The State successfully challenged this injunction, but the EPA Regional Administrator announced a federal prohibition on new hookups if the state did not create a new independent sewage authority.

Three weeks later, the Massachusetts Legislature passed and Governor Michael Dukakis signed a bill creating the Massachusetts Water Resources Authority (MWRA) and granting it responsibility to take over and rebuild the MDC sewer system.[11] Unlike the MDC, the MWRA could raise its own revenues. Soon afterwards, in January 1985, the revived federal case confronted MWRA; now the EPA, as plaintiff, alleged violations of its administrative orders, the CWA, and MDC's federal permits.[12] The U.S. District Court, finding MWRA liable for the MDC's acts, imposed a comprehensive schedule for upgrading the MWRA system, with the cessation of ocean sludge dumping as a most pressing item.

The principal goal of the system upgrade was the construction of a secondary treatment plant on Deer Island. Once complete, the plant will operate both primary and secondary wastewater treatment facilities. Primary treatment capacity will be 1.27 billion gallons per day; secondary treatment capacity will be 1.08 billion gallons per day.[13] **Table 1** compares the two.

TABLE 1:
POLLUTION-PREVENTION COMPARISON OF WASTEWATER TREATMENT OPERATIONS

Primary Only	Secondary
– removes 60% of solids	– will remove 90% of solids
– removes 40% of toxic pollutants	– will remove 85% of toxic pollutants
– reduces BOD* by 35%	– will reduce BOD by 85%.[14]

*Biological Oxygen Demand, a measure of the oxygen-consuming organic matter present in effluent. BOD is a pollutant because it removes oxygen necessary for fauna from the marine or aquatic environment.[15]

After the secondary treatment plant on Deer Island is fully operational (the court schedule requires this by 1999[16]), the MWRA will downgrade the Nut Island Treatment Plant to a headworks, making it the central collection point for the southern sector of the sewer system.[17,18] Nut Island will screen the sewage and then convey the wastewater via a five-mile, deep rock tunnel (expected to be completed in mid-1997) to Deer Island for complete treatment.[19] In addition, an outfall tunnel expected to come online in 1998 will contain 55 diffusers and discharge effluent, diluted by 100,150:1, some 9.5 miles seaward of Deer Island.[20]

Options for Sludge Disposal

Prompted by court order, as well as passage of the 1988 federal Ocean Dumping Ban Act (which was implemented Dec. 31, 1991), MWRA ceased the discharge of sludge into the Harbor in 1991.[21] Facing the enormous problem of disposing 400,000 gallons of sludge per day[22], the MWRA considered and rejected the following three options[23]:

- **Landfilling.** This was not practical in the Boston area primarily because of high land costs; the vast quantity of sludge would require a substantial area of land for an indefinite period of time.[24] Also, landfills must be capped and sealed and require toxic-containment precautions in their construction.
- **Deep Sea Dumping.** Scientists at Woods Hole Oceanographic Institution initially proposed sites at one of the deepest areas in the Atlantic; powerful hoists would have lowered sludge 4.8 km deep in leak-proof buckets.[25] This idea generated much animosity, and the Ocean Dumping Ban Act essentially blocked it anyway.
- **Incineration.** The chief advantage of this option was that it reduced volume by a factor of seven, decreasing landfill and transportation costs.[26] Other advantages included the reduction or destruction of chemical pollutants, bacteria, and viruses and the potential to produce electricity. But problems overshadowed any benefits. Locating an incineration site within a metro area was problematic, raising the risk of liability as well as environmental justice concerns. Furthermore, toxics within the sludge become concentrated in ash, making it difficult both to handle and to landfill, as rain may cause toxic substances to leach out and contaminate ground and surface waters.

The final alternatives for the MWRA centered on **reuse**. Within this category, composting and dry heating were possibilities. Composting involves dewatering the sludge and then adding a bulking agent, vastly increasing volume. For this reason, MWRA rejected composting in favor of dry heating as the solution to sewage sludge disposal.[27]

The Chosen Alternative: Pelletization

Operations

Out of two dozen proposals, MWRA selected the New England Fertilizer Company (NEFCo) and its Biosolid Drying Process.[28] NEFCo's dry-heat process converts sludge into low-nutrient, organic fertilizer pellets, thus reusing nutrients while minimizing the harmful effects from other disposal techniques.[29] On December 24, 1991, ocean-dumping of Boston's sewage sludge ceased, and the Quincy Pelletization Plant began operations.

Pelletization is not a new technology, and the Quincy plant is one of several in the country. For example, Baltimore, Houston, New York City, Tampa, and Cobb County (Georgia) operate some type of pelletization process; Milwaukee has produced sludge pellets for 60-some years.[30]

MWRA sludge is an end-product of Deer and Nut Islands' treatment of wastewater from 2.5 million people and 5,500 businesses in 43 communities.[31] The two plants process an average of 370 million gallons of sewage a day, separating it into wastewater and solids.[32] The wastewater is chemically disinfected with chlorine and then discharged into Boston Harbor. The solid material (raw sludge) is moved to digesters; there, microbes decompose the organic solids, destroying almost all the disease-causing pathogens.[33] After completing their life cycle, the microbes accumulate as digested sludge or "biosolids." MWRA then ships this colloidal mass by barge to the Quincy Pelletizing Plant.

The sludge, which can contain up to 97% water, is pumped from the plant's storage tanks, mixed with a coagulating agent, and pressed with wide fabric belts. The belts compress it into sheets and remove water (which is piped back through the sewers to the Nut Island plant). The resulting solid, called sludge cake, contains roughly 25% solids and 75% water. This sludge cake is then baked in 320° C "tumble-drying" ovens that destroy all pathogens and bacteria, remove up to 90% of the remaining water, and rotate the sludge into the final product: "Bay State Organic Fertilizer Pellets." NEFCo either packages the pellets into 40-pound bags for retail in local garden shops or stores them in silos for shipment by rail out of state.[34]

The Quincy Plant occupies about six acres of an abandoned shipyard (which was capped before construction to prevent leaching of heavy metals). Built to allow for internal expansion and upgrades without external growth,[35] the plant operates four days a week, runs two shifts per day, and produces approximately 30 tons of pellets daily. Current facilities include four million-gallon liquid storage tanks, two filter-belt presses, four sets of tumble-dryer ovens, and five storage silos.

As shown in **Table 1**, secondary wastewater treatment removes more sludge than does primary treatment alone.[36] Once secondary treatment begins at the new Deer Island facility, the Quincy Plant will increase to three shifts per day seven days a week to produce 160–170 dry tons daily (62,000 tons annually).[37]

Regulations

The Quincy Plant, the entire MWRA wastewater system, and community and industry inputs are all strictly regulated to meet aesthetic and public health standards. For instance, the plant has pressurized rooms and dry-scrubber air filters to alleviate odors and airborne diseases; Regenerative Thermal Oxidizers™ burn waste air from the pellet dryers to kill pathogens.[38] The plant boasts of operating for over two years without a single odor complaint related to the process.[39]

Additional regulations govern the sale and use of the organic product, both in handling and use on the land. NEFCo's biosolid drying technique meets federal criteria for pathogen content and vector attraction reduction.[40] For land application, Bay State Organic fertilizer pellets must meet U.S. and Massachusetts standards[41] (see **Table 2**). Secondary treatment at Deer Island will process 85% of the toxics and heavy metals that primary treatment currently leaves behind.[42] At present, MWRA landfills pellets that are out of standard due to high concentrations of metals; after full operation of secondary sewage treatment, MWRA predicts it will cease all landfilling of pellets.[43] NEFCo pellets must also conform to any applicable regulations imposed by recipient states, or they won't be bought.

TABLE 2: SLUDGE PELLET METAL CONCENTRATION (PPM) IN RELATION TO STATE AND FEDERAL LIMITS FOR LAND APPLICATION

Metal	MWRA pellets[a]	State limit[b]	Fed. limit[c]
Arsenic	2.5	n.a.	41
Boron	13.4	300	n.a.
Cadmium	6.3	14	39
Chromium	64.0	1,000	1,200
Copper	745.7	1,000	1,500
Lead	227.5	300	300
Mercury	5.7	10	17
Molybdenum	12.8	25	18
Nickel	36.0	200	420
Selenium	2.5	n.a.	36
Zinc	982.3	2,500	2,800

[a]Average concentration measured in sludge pellets during 1992.

[b]Type I standards, Massachusetts Department of Environmental Protection Reg. 310 CMR 32.

[c]High-quality sewage sludge destination, CWA part 503.

Economics

The economic benefits of pelletization were a leading factor in MWRA's choice of this sludge disposal option.[44] The greatest savings came from the pellet processing plant itself. When compared to the most feasible options of similar size, such as composting or alkaline pasteurization, biosolid drying requires only about one-third the capital costs and demonstrates competitive operating expenditures.[45]

Probably the most noticeable advantage to biosolid drying is that the final product is typically 0.5–7% of its initial volume.[46] The pellets are also lighter than wet sludge, thus minimizing transportation and handling costs. Although today every dry ton of pellets only returns about $40 of the approximately $350 it costs to produce,[47] MWRA is willing to lose money in this operation: other forms of sludge disposal, such as landfilling, would cost more. According to an MWRA official,

> if [pelletization] were profitable, the private sector would have already done it. We never intended this to be profitable. It was the lowest cost option in 1988 [when we made the decision].[48]

Pelletization facilitates reuse of a potentially detrimental resource that would have to be disposed of in any event.

Fertilizer Benefits and Marketing

The sludge pellets are a 100-percent recycled, organic fertilizer, marketed under the name "Bay State Organic."[49] Even though their nitrogen:phosphorus:potassium (NPK) value is only 3:2:0, the pellets contain several other macronutrients (calcium and sulphur) and micronutrients (iron, copper, zinc).[50] NEFCo's biosolid drying process helps maintain and even enhance the sludge's value as a fertilizer, and it has the technology to add fertilizer components to tailor the product to the user's need.[51] Compared with typical chemical fertilizers, the pellets

- contain more than 75% water-insoluble nitrogen (a form that will not leach to groundwater)[52]
- are compatible with fertilizer blends,
- can serve as a product conditioner, and
- improve soil quality by adding organic material and increasing water retention.

About 10% of the product is sold and distributed in Massachusetts. Because the 43 communities served by MWRA fund the wastewater treatment and pelletization plants, they receive free pellets, which they primarily use for turf application in golf courses, parks, and cemeteries.[53] NEFCo markets the pellets to the general public of Massachusetts, but to a lesser extent; locals can purchase them from gardening stores for about $3 per 40-lb. bag.[54] Some pellets are sold to farmers in Colorado and Arizona for use as a soil conditioner in clear-cut forest replanting and strip mine revegetation. Florida citrus farmers used to be another outlet, but New York City's more heavily subsidized pellets have taken over this market.[55] Today, a fertilizer blender in Ohio purchases the majority of NEFCo pellets.

The secondary treatment at Deer Island, starting in 1999, will produce better quality sludge. The greater quantity of microorganisms, and the increased length of time they have to digest the sludge, will allow them to strip more nutrients from wastewater; this means fewer nutrients released into the Harbor and more absorbed into the sludge and pelletized.[56] NEFCo plans to eventually mix sludge produced from primary and secondary treatment in a 1:1 ratio. Increased microbial absorption during sewage processing will elevate pellet NPK values and fertilizer quality, making Bay State Organic more marketable both in and out of Massachusetts.

System-Wide Cleanup

Other parts of the Clean-up Project also represent moves up the pollution prevention hierarchy. As described below, improvements in pipeline infrastructure will reduce untreated ocean discharge of wastewater, and the choice of pelletizing prompted industrial wastewater pretreatment so the pellets would comply with land application standards.

Combined Sewage Overflows and Sewer Pipe Replacement

During periods of extreme rain or snowmelt, standard sewerpipes can overflow, usually into pipes called combined sewer overflows (CSOs). In many cases these CSOs dump the combined sanitary waste and stormwater runoff directly into rivers and tributaries. For Boston Harbor, court-ordered actions have reduced overflows of raw sewage to the harbor and improved efficiency of the sewage system. CSO upgrades resulted in extending treatment to more of MWRA's wastewater. MWRA must upgrade all existing CSOs to provide screening and chlorination before releasing waste directly into the harbor and its tributaries[57], a shift from "controlled discharge" to, albeit slight, "waste treatment." As the overall system improves, MWRA will systematically close CSOs, and untreated and treated flows from outfalls will approach zero.[58,59]

CSO improvements are arguably the most visible upgrades within the Boston sewer system. Within the last five years, MWRA has installed screening and chlorination in all CSOs located at treatment facilities.[60] In addition, the Authority closed 40 CSOs completely, bringing the active number down to 68.[61] These actions have led to a more efficient system of sewage collection and helped reduce raw sewage discharges to the harbor.

MWRA has also begun systematic replacement and enlargement of collection pipes. Efficient water transportation decreases the contamination of groundwater. Larger pipes reduce back-ups in the system, decreasing the outflow from CSOs. Replacing corroded sections in collection tunnels decreases inflow and infiltration, reducing the amount of water requiring treatment by up to 60%. This refurbishment also helps locate illegal hook-ups and remove old lead solder, which is one of the major sources of this toxic metal.[62]

Reduction and Control of Toxics

Probably the most important pollution prevention initiative was the creation of the Toxic Reduction and Control (TRAC) Task Force. The Massachusetts Department of Environmental Protection (DEP) land application criteria (see **Table 2**) give MWRA a strong incentive to reduce the amounts of toxics and metals in digested sludge. Even the most advanced municipal treatment systems can do little to eliminate these contaminants.[63] Source reduction was essential, if in-state marketing of Bay State Organic fertilizer was to become feasible. If not, MWRA would likely have to resort to costly landfill disposal. The solution was industrial pretreatment.

Once the DEP set pellet standards, MWRA determined the daily allowable amounts of toxics tolerable by the system. TRAC divided these quantities among the contributing industrial facilities and began to enforce compliance. TRAC offers technical assistance to industrial sources (material substitution or reuse opportunities) and has the authority to perform surprise inspections and secret monitoring, to assess and collect an ascending schedule of fines for non-compliance, and to revoke industrial discharge permits. TRAC also manages the septage hauler permit program for non-sewered communities, another important source of toxic metals, especially lead and copper. Since TRAC's inception, MWRA has reduced toxics reaching Deer Island, enabling the pellets to meet DEP specifications the majority of the time.

Problems remain, however. Molybdenum is one, and is the subject of a TRAC-sponsored voluntary product substitution campaign. Effluent concentrations of this metal used for corrosion control still exceed the DEP criterion in cooling season because of molybdenum discharges from cooling tower facilities. TRAC estimates that 5,000–8,000 commercial and residential cooling towers operate in the service district. Currently, TRAC does not require cooling towers to have discharge permits. In the spring and summer of 1995, TRAC contacted area chemical suppliers and urged a transition to phosphate-based substitutes. In a fall 1995 followup, TRAC found some success from vendors although some of their clients could not be switched without serious problems to their systems. Elsewhere, voluntary efforts from the MWRA Mercury Products Work Group, consisting of representatives from TRAC and its regulated community, have also been effective in identifying and eliminating sources.[64]

Due to the work of TRAC, MWRA has reduced contaminants at the source, encouraging source reduction, and chemical substitutions within industry.[65] Benefits include the improved efficiency of the waste-water treatment plants and reduced pellet landfilling. While MWRA is still occasionally out of compliance with federal and state regulations,[66] Boston no longer deposits sludge in the harbor, and upgrades will end the discharge of raw sewage from CSOs. Even though MWRA presently practices all waste management options, except uncontrolled release, the Authority is committed to attaining the highest positions of the pollution prevention hierarchy.

Conclusion

Upgrading Boston's sewage treatment system in 1977 would have cost the local community $80 million, with a total project expenditure of $800 million; as of 1996, the running total was $4.3 billion.[67]

The sheer scale of the Boston Harbor Cleanup Project makes it an important subject of coastal policy. Moreover, other U.S. coastal cities share Boston's concerns about a decaying infrastructure.[68] Thus, pollution prevention's role in the cleanup is clearly of interest to policy officials. P2's limiting factor in in Boston, however, is land use: high land costs make internal reuse of sludge prohibitively expensive. Thus, the biggest opportunities for pollution prevention for Boston Harbor probably lie in growth management. While technological source reduction options do exist[69], they are not cost-effective in densely populated urban centers like Boston. While source reduction has occurred as part of the cleanup (with the removal of leaded solder and with industrial pretreatment), the most important cleanup efforts have been, first, to upgrade treatment and extend it to more of Boston's wastewater and, second, to promote external reuse of sewage sludge. While the pollution prevention hierarchy is a holistic and comprehensive tool for assessing waste management options, it does not obviate economic concerns.

Since the creation of MWRA, metropolitan Boston's sewage collection and treatment has improved. Beginning in 1999, secondary treatment will remove an additional 22.5 tons of nitrogen and 2.5 tons of phosphorus from wastewater per day.[70] Daily effluent discharges will contain 8 tons of nitrogen and 2.5 tons of phosphorus, reductions of 75% and 50% from 1996 values. Moreover, MWRA predicts that BOD and total suspended solids loadings will decrease by 90% from the 1990 levels.[71]

With the installation of the Quincy Sewage Sludge Pelletizing Plant and the subsequent cessation of sludge dumping in Boston Harbor, MWRA initiated a recovery program for local waters. Indices of health of benthic organisms show substantial improvements in the past decade. Similarly, concentrations of toxic substances in Boston Harbor shellfish, fish, and lobster have decreased.

Boston has made noticeable strides to improve the MWRA's sewage system. While comprehensive source reduction is not economically feasible at present in urban wastewater management, MWRA has achieved this goal with toxics and heavy metals. Although most parts of the Clean-up Project are not source reductions, MWRA now treats more of its wastewater and at higher levels. Moreover, MWRA has promoted reuse of sludge, one of the most biologically damaging sewage byproducts.

Endnotes

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Discussion Questions

1. MWRA exports the majority of their sludge pellets out of Massachusetts. The primary destinations of this fertilizer are fields in Arizona and Colorado. What responsibility should MWRA have to monitor the effects of their sludge pellets once they have left the pelletizing plant?

2. MWRA has chosen treatment more often than "pollution prevention" while complying with imposed regulations.

   a. Is it more efficient to impose specific types of waste management, or should state and federal authorities simply establish standards and allow businesses and municipalities to comply how they see fit?

   b. Through which method would MWRA achieve "source reductions" more quickly, and why?

3. Since MWRA has been under the court schedule for upgrades within the sewage system, average sewage rates per household have increased form $60 to $750 annually.

   a. Should rate payers bear the brunt of these upgrades?

   b. Because Harbor users receive the benefits of cleaner water, should fishermen and others share in the cost of these upgrades?

   c. What steps might have been, and may still be implemented to help alleviate the burden on rate payers?

4. The fact that industrial wastewater enters the municipal sewage system is an accident of history: it was just too expensive to build an entirely separate system for industry, so it was connected to the general system. However, the bulk of the toxic material that enters the waste stream comes from industrial sources.

   a. Should industries have to pay extra for the disposal of their effluent, rather than distributing the costs among all users of the sewage system?

   b. How might the use of toxic chemicals be reduced, in terms of both household and industrial users?